MAUI [HAWAII]

AMOS

fall 2003

Air Force Research Laboratory
DETACHMENT 15

OCEANIT UNCONVENTIONAL TELESCOPE IS A BREAKTHROUGH

KStar Telescope

BASED ON A NEW REVOLUTIONARY OPTICAL PRINCIPLE, THE KSTAR TELESCOPE ACHIEVES AN UNPRECEDENTED DIFFRACTION LIMITED FIVE-DEGREE FIELD OF VIEW WITH SINGLE PIXEL RESOLUTION OVER THE ENTIRE FOCAL PLANE. TRADITIONAL HIGH-PERFORMANCE OPTICAL SYSTEMS USE ASPHERICAL OPTICS THAT ARE DIFFICULT AND EXPENSIVE TO FABRICATE. IN CONTRAST, THE KSTAR USES LOW-COST EASY-TO-FABRICATE SPHERICAL OPTICS IN A PATENTED CONFIGURATION TO PRODUCE A NEXT GENERATION OPTICAL SYSTEM, THAT IS ALSO RUGGED, PORTABLE, AND EASY TO PRODUCE.

Oceanit's senior optical engineer, Dan O'Connell, has been the lead on the development of this telescope over the past three years and is excited about the feedback he's received from the astronomy community. Mike Palermiti, a Florida-based astronomer and consultant, says, "The KStar will do to small telescopes what the internal-combustion engine did to horse buggies." O'Connell comments, "its wider field of view will allow more observation of the sky in much less time. With the KStar, it's like looking through seven conventional telescopes at once."

The KStar is initially installed in Kihei, Maui, as the first step in the development of a worldwide network of optical sensors to more accurately measure, determine, and catalog the orbits of objects in Low Earth Orbit (LEO). Because the design allows wide field of view implementations at a lower cost, the KStar is capable of supporting a broad range of applications and customers, including astronomy, homeland defense, and academic customers. The KStar will also allow the offloading of fundamental tasks from larger, more expensive telescopes onto the KStar, freeing up the larger telescopes for new, more important work.

To support a broad range of applications, the KStar is modular in design and includes such options as: kinematic field of view (FOV) modules, kinematic spectral bank pass modules, and kinematic accessory instrument modules, and is scalable to large apertures (250 mm to 2 m class) and in F-Stop number (F/0.7 to F/5). The KStar's primary optical elements are manufactured to be lightweight and the optical tube assembly incorporates carbon fiber technology, resulting in a rugged compact portable telescope system.

Oceanit is fabricating the optics and doing the final system assembly at its newly opened Maui Optical Systems and Imaging Center (MOSAIC), located at the Maui Research & Technology Center (MRTC). Fabricating and assembly time is reduced due to the KStar's patented use of spherical optics, making the KStar the most cost-competitive telescope in its class. Regarding MOSAIC, Oceanit's new optical design and fabrication lab, "we intend to build and foster new economic opportunities and world-class optical capabilities on Maui" says Dan O'Connell.

Images taken with the KStar Telescope

3.6 - meter
AEOS telescope

AEOS Photometry of Spheres

Many satellites currently being developed and deployed are much smaller in size than their predecessors. Such "micro-satellites" have typical sizes of roughly 30 cm or less, and, even when stationed in very low-altitude orbits, cannot be spatially resolved using the most powerful ground-based optical imaging systems. Information about the size, albedo, shape, orientation, and rotational state of such satellites must be obtained through non-imaging techniques. To address this need, AMOS has developed a program to obtain calibrated photometry of moving targets using the 3.6 m AEOS telescope.

The observations employ the AEOS Visible Imager (VisIm) instrument using a Bessel I-band filter (700-900 nm). Data acquisition consists of obtaining VisIm observations of one or more moving targets intermixed with several photometric standard calibration stars. An integrated tool for data reduction processes the data in an automated fashion yielding several data products, including nightly instrumental calibration parameters as well as animations of the moving object photometry. The calibrated photometry provides the means to estimate optical cross sections as well as the means to characterize the object's rotation state. Observed light-curves of uncontrolled, tumbling objects display clear periodic variations that are readily distinguishable from those of stabilized satellites.

Satellites in Low Earth Orbit (LEO) typically make distinct passes over the observatory that last roughly 5-20 minutes. Photometric observations entail acquiring the object as quickly as possible during the pass and recording VisIm CCD data thereafter for as long as possible. Reflected sunlight dominates satellite emission in the I-band, and observations of LEO objects can be challenging because the observatory must be in darkness during the observations to limit the foreground sky brightness, while the satellites passing above require solar illumination to be detected. This restricts I-band photometric observations of LEO satellites to limited periods near dawn and dusk.

Over the past decades, several spherical satellites have been inserted into orbit for use as radar or optical calibration objects. Because most are too distant or too small to be resolvable, the calibration spheres provide a convenient means of testing and verifying techniques of non-resolvable object photometry. We use photometric observations of calibration spheres to illustrate how photometry can provide estimates of satellite albedos. In particular, we discuss two calibration spheres that serve to illustrate very different satellite reflectance properties: the bright diffuse reflector SSN 1520, and the bright specular reflector SSN 1361.

Object 1520 Calsphere-4(A)

Calsphere-4A (SSN 1520, 1965-065H) was launched in August of 1965, and currently occupies a 1077 km x 1181 km x 90.1° orbit. It is a 0.36 m diameter sphere made of aluminum and painted white before launch. Several AEOS VisIm photometric observations of SSN 1520 have been conducted, and Figure 1 shows the calibrated magnitudes recorded during a ≈10-minute pass on January 18, 2003. During the pass the observatory-to-satellite range varied considerably, and the peak brightness in Figure 1, measured at ≈05:56:30 UT, corresponds to the minimum range of R = 1273 km. Figure 1 also shows the best-fit two-component model for SSN 1520 (solid line), with specular albedo = 1.2% and diffuse albedo = 67%. The relatively small specular albedo indicates that SSN 1520 is nearly a purely diffuse reflecting sphere. The best-fit diffuse albedo

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of 67% is a bit lower than the ≈85% total albedo expected for fresh white paint. However, SSN 1520 has been on-orbit for 38 years, and this discrepancy suggests that the white paint may have darkened due to space weathering. The very small specular albedo also could be due to weathering making the white paint more powdery and less shiny over time.

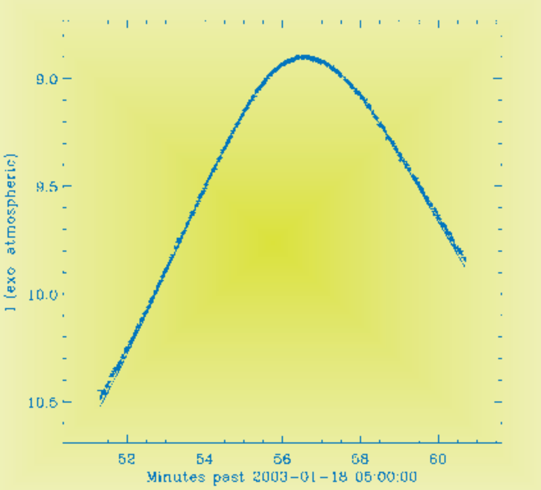


Figure 1. *Exo-atmospheric I-band (700-900 nm) magnitudes for calibration sphere SSN 1520 measured by the AEOS VisIm instrument on January 18, 2003 (+ symbols) plotted with the best-fit two-component reflectivity model (solid line). The plus sign symbols show the calibrated exo-atmospheric magnitudes. The solid line shows the best-fit model that uses a diffuse albedo of 67% and a specular albedo of 1.2%.*

Object 1361 LCS-1

Lincoln Calibration Sphere-1 (SSN 1361, 1965-034C) was launched in May of 1965, and currently occupies a 2780 km x 2797 km x 32.1° orbit. It is a 1.13 m diameter sphere made of unpainted aluminum. Several AEOS VisIm photometric observations of SSN 1361 have been conducted. Figure 2 shows the calibrated magnitudes recorded during a ≈10-minute pass on December 15, 2003 that ended when the satellite entered the Earth's shadow and dimmed to below detection threshold. Figure 2 also shows the best-fit two-component reflectance model for SSN 1361 (solid line), with specular albedo = 59% and diffuse albedo = 5.2%. The relatively small diffuse albedo indicates that SSN 1361 is mostly a specular reflector. The best-fit specular albedo of 59% for SSN 1361 is not surprising for unpainted aluminum exposed to 38 years of space weathering.

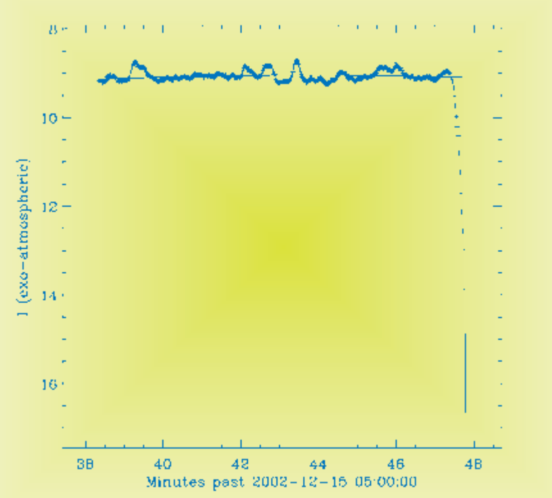


Figure 2. *Exo-atmospheric I-band magnitudes for calibration sphere SSN 1361 measured by the AEOS VisIm instrument on December 15, 2003 (+ symbols) plotted with best-fit two-component reflection model (solid line). The measurements clearly show the satellite rapidly dim as it enters Earth's shadow near 05:47:30 UT. Before shadow entry, the data also indicate the existence of ±0.5 magnitude variations time scale of ≈30-60 seconds. The solid line shows the best-fit reflection model that uses a diffuse albedo of 5.2% and a specular albedo of 59%.*

The light-curve in Figure 2 also clearly shows that, before shadow entry, SSN 1361 showed coherent ±0.5 magnitude variations on a time scale of ≈30-60 seconds. The variations are not associated with changes in target range or phase angle, and appear consistently in all other VisIm observations of SSN 1361. These variations may be caused by surface irregularities on the sphere. If this were the case, then the 30-60 second variation time scale is likely associated with the rotation period of the satellite. Preliminary analysis indicates that relatively small (≈5%) irregularities in the radius of the sphere could, in principal, account for the ±0.5 magnitude variations; similarly, a "patchy" specular albedo pattern, with isolated regions on the sphere where specular albedo ≤0.25, could also explain the observed variations.

Observed fluxes from other, non-spherical satellites generally show more complicated light-curves than those plotted in Figures 1 and 2. In particular, derelict rocket-bodies tend to show periodic variations in their light-curves that indicate these uncontrolled bodies are tumbling. Similarly, three-axis stabilized satellites tend to have smoother, non-periodic light-curves. This distinction may be used as a means to quickly discriminate stabilized payloads from upper-stage rocket bodies.

to estimate target optical cross
ze the object's rotation state.

MHPCC to Play Key Software, Data Processing, and Storage Role in PanSTARRS Project

MHPCC (Maui High Performance Computing Center) will play a key software development, data processing, and storage role for the PanSTARRS (Panoramic Survey Telescope and Rapid Response System) that is currently under development. PanSTARRS is a University of Hawaii project funded through a series of grants from the Air Force Research Laboratory.

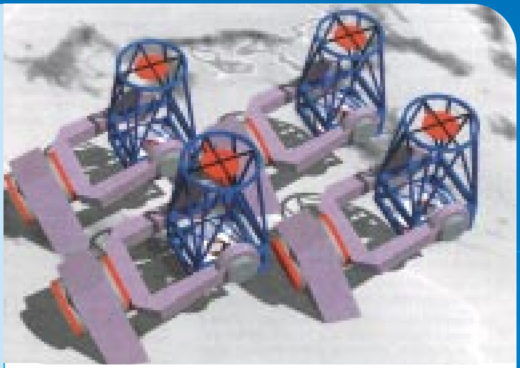
The University's Institute for Astronomy (IfA) leads this effort to design and implement an astronomical survey system to search for potentially Earth-impacting asteroids. The engineering team consists of members from IfA, MHPCC, SAIC, and Lincoln Labs. Due to MHPCC's location and history of high performance computing and data processing, IfA has selected MHPCC to play a key role in the data processing portion of this large project.

PanSTARRS, an array of four small telescopes with very large fields of view, will image an area about 30-40 times that of the full moon in a single exposure. Combining an array of small telescopes with billion pixel CCD cameras and sophisticated data storage and mining capabilities will create a more powerful survey resource than all existing telescopes combined. Besides identifying potentially dangerous asteroids, PanSTARRS's ability to detect very faint or moving objects will enable astronomers to address many scientific questions, ranging from the origin of the solar system to the properties of the universe. By applying data mining technology to search space for similar objects using existing digital sky surveys, astronomers have found things they weren't looking for, such as the numerous but very faint brown dwarf stars. Requiring years to complete, the existing surveys provide only a snapshot in time. PanSTARRS will create an equivalent survey each week, capturing a detailed history of time variability.

Each night of observation, PanSTARRS will generate up to 6 terabytes of raw data that must be processed to produce usable images. MHPCC is heavily involved in engineering the software and facilities that will enable this data to be processed. While engineering on the data processing side of the project is ongoing and subject to change, the project has generated some rough capacity sizing of the effort that has generated the internal MHPCC nickname of the project "The Tera Project."

Total Processing Capacity:	*1 TeraHertz, 1 TeraFlops (~256 x 4GHz processors)*
Total Main Memory:	*1 TeraBytes (~256 x 4 GBytes)*
Daily Data Throughput:	*24 TeraBytes/Day*
Total Hard Disk Drive:	*100 TeraBytes*

MHPCC is excited and proud to have a key role in this leading edge, ambitious engineering project.



PanSTARRs is envisioned as an array of four small, high sensitivity, wide-field-of-view telescopes.

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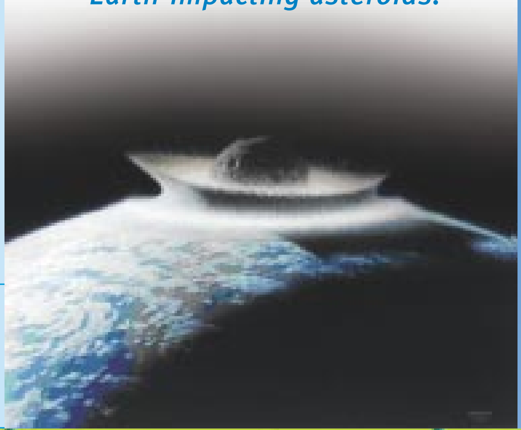

Artist's concept of catastrophic asteroid impact with Earth.

Image courtesy of NASA.

MSSS Lyot Project, the Focus of American Museum of Natural History

In April 2003, a film crew from the American Museum of Natural History in New York City was at the MSSS filming a short documentary on infrared astronomy with an emphasis on the search for planets orbiting other stars. The documentary will be shown at the museum, NASA science centers, and other museums around the country. The film crew was at MSSS because the Museum is the lead institute in the Lyot Project.

American Museum of Natural History Film Crew

The Lyot Project is one of the astronomy programs at AEOS funded by the National Science Foundation and the Air Force Office of Scientific Research. The Lyot Project is building an infrared coronagraph optimized for the detection of planets orbiting other stars. This coronagraph will be the most advanced coronagraph ever developed for stellar work.

While coronagraphs were first designed to study the Sun's corona, they are also used to block the light from a star and study faint objects around the star such as companion stars, dust disks and, hopefully soon, planets. The Lyot Project coronagraph will be mated with the AEOS adaptive optics system. The adaptive optics system removes the image blur caused by turbulence in the Earth's atmosphere. Since the blurring is removed, light from the star is concentrated in a much smaller spot. This smaller spot allows the coronagraph to remove just the light from the star and leave behind the light from the planet. The coronagraph will be using infrared light because planets are brighter in the infrared than in the visible and stars are fainter in the infrared than the visible. This provides the best chance for detecting a planet. The Lyot Project coronagraph is expected at the observatory in October 2003.

The film crew picked this time to come to Maui, because the infrared camera being built for the Lyot Project is being used in a study of atmospheric turbulence. This project was funded by the Air Force Office of Scientific Research. The turbulence study is conducting several experiments to test theoretical predictions of the behavior of turbulence in the Earth's atmosphere. Further details of the Lyot Project and the atmospheric turbulence study will be given at the AMOS Conference in September 2003.

CONFERENCE UPDATE

The 2003 AMOS Technical Conference
September 8 – 13, 2003
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